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Full Scale Insensitive Munitions Testing of the RAN 5"/54 Cartridge Case

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DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

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Aeronautical and Maritime Research Laboratory

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ABSTRACT

During the period May 1992 to March 1994, a series of 14 full scale Insensitive Munitions tests were conducted on RAN 5"/54 Cartridge Cases containing the standard BS NACO propellant and a Low Vulnerability Ammunition (LOVA) propellant formulation 'XM 39'. Tests were multiple bullet and fragment impact, and fast and slow cookoff. The results of these tests are presented and some implications are discussed.

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EXECUTIVE SUMMARY

The international trend towards Insensitive Munitions (IM) is becoming increasingly relevant to the Australian Defence Force (ADF), as evidenced by the fact that Australia has implemented an official Australian Defence Organisation policy on IM. This policy is espoused in DI(G) LOG 07-10, which was promulgated in November 1993.

One of the major emphases of this IM policy is the reduction of platform vulnerability to such threats as projectile impact, shaped charge jet attack, or fire. In keeping with this policy, low vulnerability ammunition (LOVA) propellants for Naval guns are being developed in Explosives Ordnance Division (EOD), based on RDX with an inert binder. These propellants are designed to have performance comparable to that of conventional propellants, but with reduced vulnerability to the threats described above.

A candidate LOVA propellant has been selected for comparison with the conventional propellant in RAN's 5"/54 Gun. Tests to compare the vulnerability of both propellants to bullet and fragment impact, and fast and slow cookoff environments have been conducted. These tests demonstrate that the conventional propellant exhibits a mixed response to both the thermal and impact stimuli, whereas the LOVA propellant reacts favourably to both thermal stimuli but may detonate when subjected to a sufficiently severe impact stimulus.

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1. Introduction

The international trend towards Insensitive Munitions (IM) is becoming increasingly relevant to the Australian Defence Force (ADF). Australia is in the process of adopting and implementing an official Australian Defence Organisation policy on IM, with the Defence Instruction (General) (DI(G)) to set implementation in train being issued in November 1993.

This DI(G) LOG 07-10[1] states that:

"IM are to be introduced into Service with the Australian Defence Organisation, where it is sensible, practicable and cost-effective to do so ... All further procurement of Defence explosive ordnance should meet the applicable Insensitive Munitions criteria at Annex A, subject to consideration of the cost benefits ..."[1]

Annex A to the DI(G)[1] lists nine hazardous stimuli to which munitions may be exposed during the logistic cycle covering both peacetime and war. When a munition is proposed to be tested against these IM criteria, a threat analysis should first be carried out to define which of the nine hazards represent credible threats. The fast cookoff stimulus, which simulates a munition engulfed in a fast burning fire, is almost certain to be a requirement in all cases, as is some form of projectile impact test. The slow cookoff test which is used to assess the response of a munition to a gradually increasing thermal environment such as could occur in a ship's magazine adjacent to a fire, may be required in some cases although it can be argued that the heating rate for the test should be based on identified likely scenarios from the threat analysis rather than the single rate specified for all munitions.

Under two tasks sponsored by RAN, Explosives Ordnance Division (EOD) is investigating a less sensitive explosives fill and a Low Vulnerability Ammunition (LOVA) propellant for the RAN 5"/54 Round. During the period May 1992 to March 1994, fourteen full scale IM tests were conducted on 5"/54 Cartridge Cases containing the standard BS NACO propellant and the LOVA propellant formulation 'XM 39'. Tests were multiple bullet and fragment impact, and fast and slow cookoff. These tests were conducted at Army's Proof and Experimental Establishment (P&EE), Port Wakefield, generally in accordance with DI(G) LOG 07-10[1], which refers to test procedures from US MIL-STD-2105A(NAVY)[2] and NATO STANAGs 4241[3] and 4240[4].

This report presents the results of these Cartridge Case tests and discusses their implications for RAN.

2. Test Items

Each test item comprised a brass 5"/54 Cartridge Case filled with either 9 kg BS NACO or 10 kg LOVA propellant.

The BS NACO propellant (lot number MEM 2157) was provided in aid by P&EE, Port Wakefield, who were also responsible for filling all of the Cartridge Cases in accordance with NOID 52205. BS NACO is a single base gun propellant comprising approximately 91% Nitrocellulose.

To minimise the response of gun propellants to hazardous stimuli, LOVA propellants based on RDX with an inert binder have been developed. The LOVA propellant XM 39 was manufactured by EOD to a US formulation which includes approximately 75% RDX, 12% Cellulose Acetate Butyrate, 8% Acetyl Triethyl Citrate and 4% Nitrocellulose.

3. Bullet Impact Tests

3.1 Test Description

The bullet impact tests were conducted in July 1992, in accordance with MIL-STD-2105A(NAVY)[2], Section 5.1.7:

'The bullet impact test is conducted to determine the reaction of the test item when impacted by at least three .50 caliber type M2 armor-piercing (AP) projectiles at a velocity of 2800 ± 200 ft/s (853 ± 60 m/s).'

The test specification nominated in DI(G) LOG 07-10[1] for the bullet impact test is NATO STANAG 4241[3], which is similar to MIL-STD-2105A(NAVY)[2] except that the STANAG offers the choice of single or multiple impacts, depending on the most likely threat to the test item identified in the threat analysis. For these Cartridge Case tests, a multiple impact test was considered to represent the 'worst case' scenario.

Two tests were conducted with each propellant type. For each test, the Cartridge Case was suspended from an 'A'-frame as shown in Figure 1 and three modified Ranging Barrels (for MG L6A1) were mounted onto a Universal Gun Mount 35 m from the 'A'-frame. The firing interval was 50 msec between each bullet and the barrels were adjusted so that at the target, all three bullets were in an approximate horizontal line with 90 mm between bullets 1 and 2 (left and centre) and 125 mm between bullets 2 and 3 (centre and right). No spatial distribution of the bullets was specified in MIL-STD-2105A(NAVY)[2]: the distribution chosen was considered to represent a reasonable spread at the target.

The ammunition for the tests was specially prepared by EOD to achieve the required impact velocity. These preparations involved disassembling existing Dutch 0.50 cal AP rounds, removing the propellant and percussion primer, inserting modified DEFA 30 mm M52 primers to allow for electrical initiation, loading the primed case with 15.4 g of the original propellant and crimping the AP bullets into the same cartridge cases.

Video cameras and a 16 mm high speed camera operating at 4000 frames per second were used to monitor and record the tests. Also, six high frequency pressure transducers were used to measure any blast overpressure. Gauge numbers 1 to 4 were mounted in a plane through the horizontal centreline of the Cartridge Case as shown in Figure 1. Gauge numbers 5 and 6 were mounted at ground level.

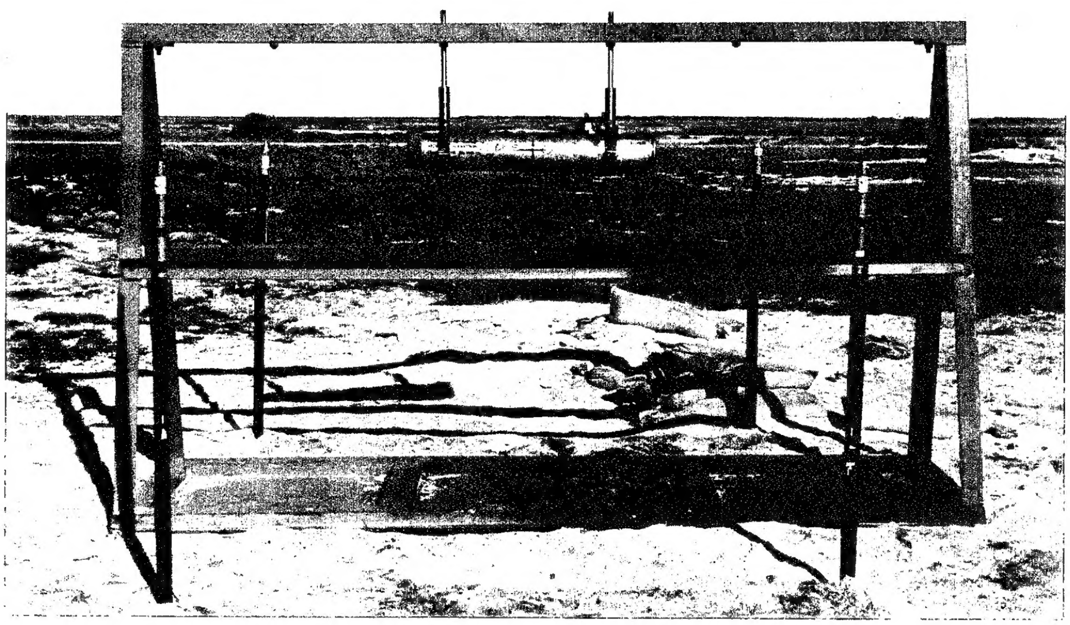

Figure 1: Bullet Impact Test setup, including four blast overpressure gauges

3.2 Results

The results in both BS NACO tests were very similar. The video and high speed film records indicate that, on impact, the propellant ignited and commenced burning. The rear side of both Cases ruptured slightly as shown in Figure 2, throwing burning and unburned propellant up to 12 m from the test site. Propellant remaining in the Cases continued to burn for approximately 30 seconds. Approximately 0.2 kg of unburned propellant was recovered after each test.

With the LOVA propellant, only a very small quantity of propellant ignited. The rear side of both Cartridge Cases ruptured significantly (see Figure 3) and the Cork Plugs were ejected from each. All burning propellant was immediately extinguished. Unburned propellant was thrown up to 40 m from the test site. After each test, approximately 9 kg of unburned propellant was recovered.

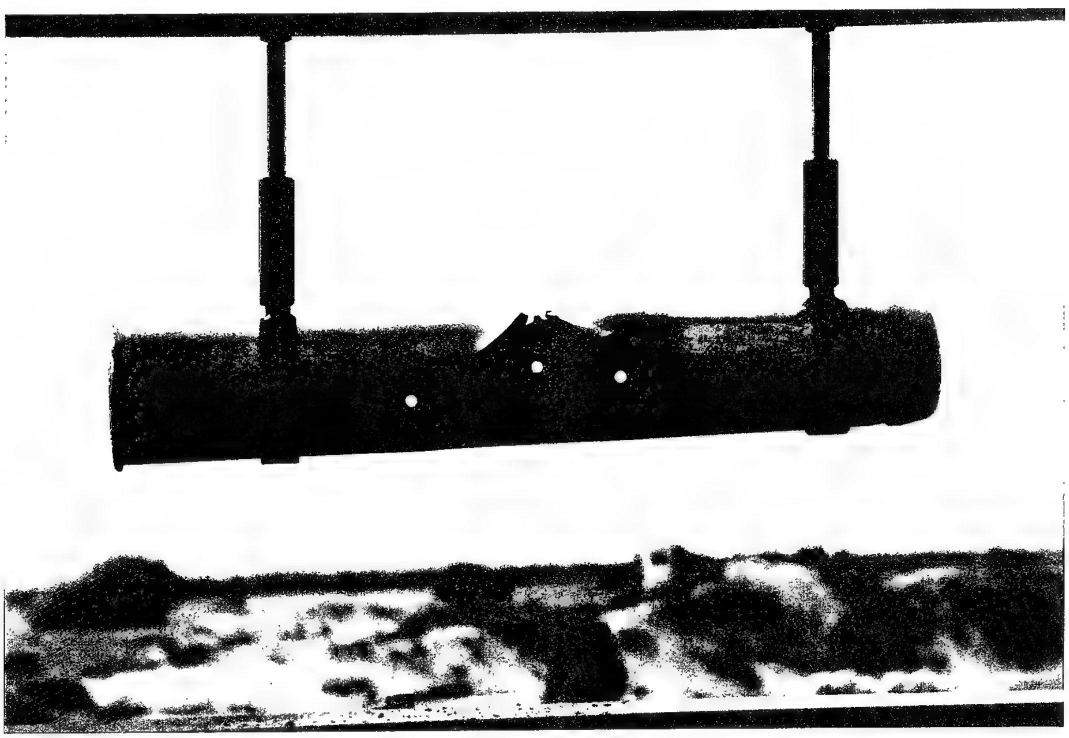

Figure 2: Rear of Cartridge Case after BS NACO Bullet Impact Test 2

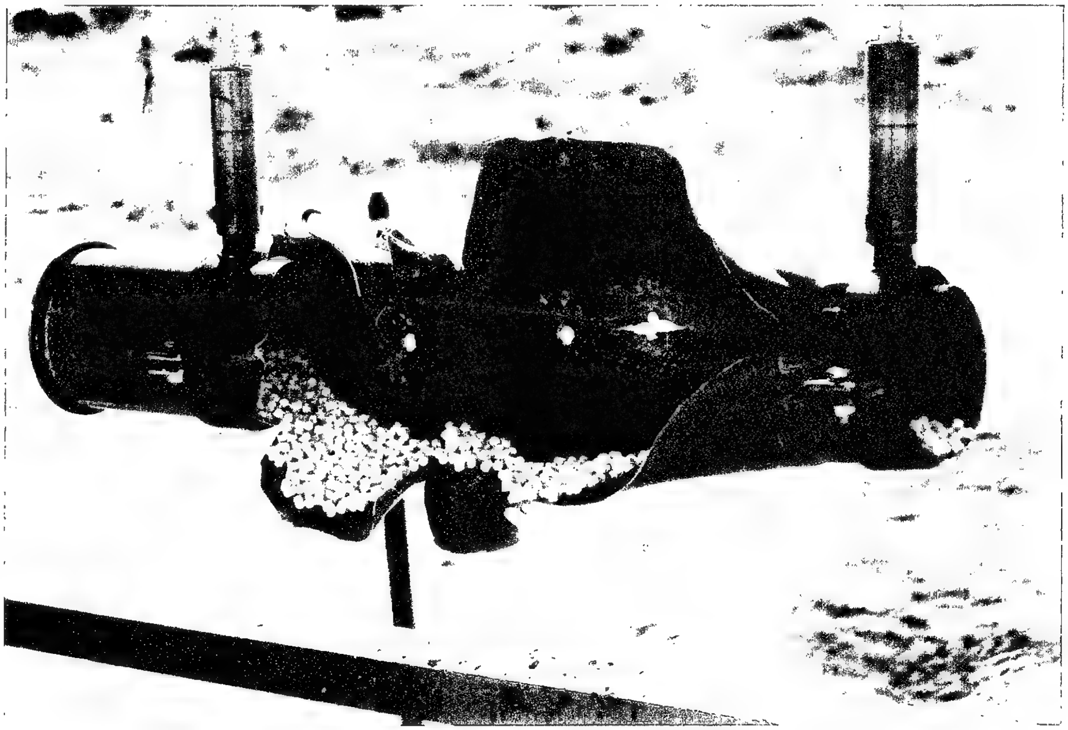

Figure 3: Rear of Cartridge Case after LOVA Bullet Impact Test 1

Table 1 shows the measured peak overpressures from the Case rupture in each test.

Table 1: Peak Overpressures - Bullet Impact Tests

Gauge Number	Horizontal distance from Cartridge Case	BS NACO Propellant		LOVA Propellant	
		Test 1 (kPa)	Test 2 (kPa)	Test 1 (kPa)	Test 2 (kPa)
1	1.5 m, forward	1.0	1.0	2.1	2.2
2	1.5 m, forward	1.2	0.7	1.7	2.1
3	1.5 m, rear	3.3	4.1	9.6	8.4
4	1.5 m, rear	2.8	3.6	9.6	11.8
5	3.0 m, rear	3.3	3.3	5.7	5.0
6	3.0 m, rear	2.5	2.8	5.5	3.7

These blast overpressure results, together with the large degree of venting observed in the bullet impact tests suggests that the LOVA propellant builds up pressure rapidly when ignited, but when the pressure is relieved the propellant quickly extinguishes. A different trend is observed with the BS NACO propellant where the initial pressure buildup and hence degree of Case venting is less, however the propellant continues to burn at ambient pressure.

4. Fragment Impact Tests

4.1 Test Description

The fragment impact tests were conducted in March 1994, in accordance with MIL-STD-2105A(NAVY)[2], Section 5.1.8:

'The fragment impact test is conducted to determine the reaction of the test item to the impact of two to five one-half inch (12.7 mm), 250 grain (15 g), mild-steel cubes travelling at 8300 ± 300 ft/s (2530 ± 90 m/s).'

Again, two tests were conducted with each propellant type. For each test, a blast shield was placed at the site. A wooden stand was placed 1.8 m to 2.4 m in front of the shield and the Cartridge Case was supported on a wooden trestle 2.1 m to 2.8 m behind the shield, as shown in Figure 4. During the first test of both propellant types, a 12.7 mm steel plate was placed immediately beneath the Cartridge Case as a horizontal witness plate. Vertical aluminium witness plates were suspended 0.6 m behind the Cartridge Cases for all tests.

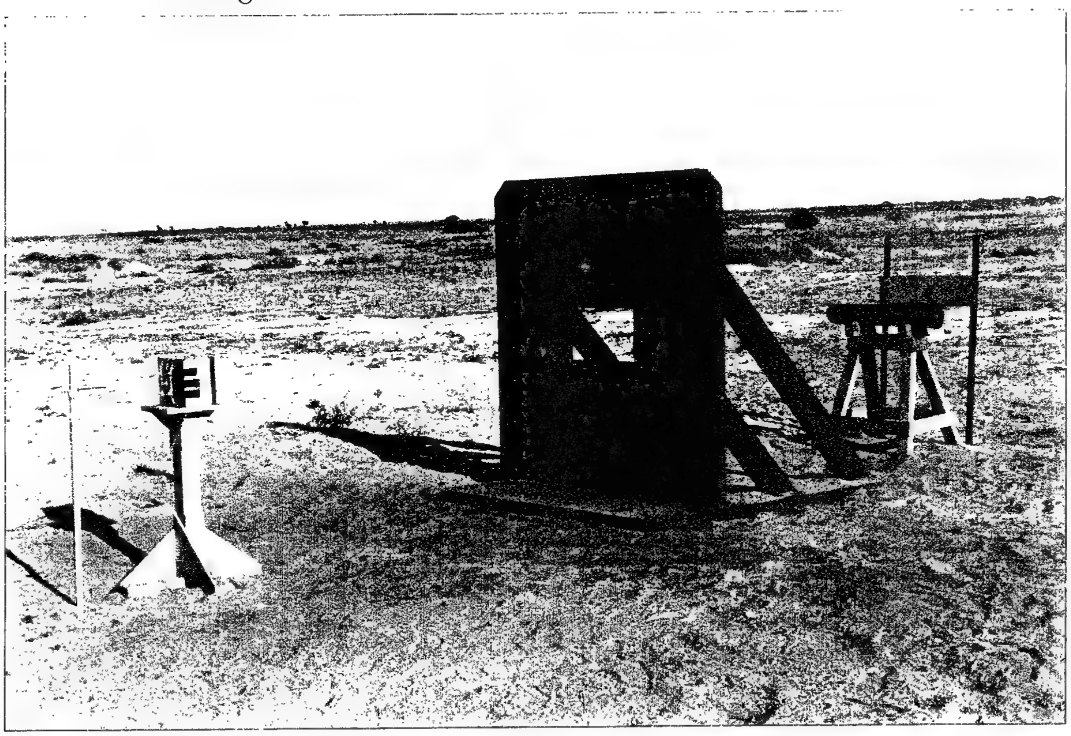

Figure 4: Fragment Impact Test setup

When each Cartridge Case was in position, a fragment projector was placed on the wooden stand in front of the blast shield. The fragment projector comprised two parts: an explosive charge and a FRAGMAT. The explosive charge consisted of

approximately 9.5 kg of cast Composition B, Grade B (RDX/TNT 55/45) in a 203 mm x 203 mm x 150 mm long (internal dimensions) box fabricated from 12.7 mm plywood. The FRAGMAT was manufactured by firstly tack-welding four pieces of steel to form a frame with internal dimension 67 mm square. Twenty-five 12.7 mm mild steel cubes were then epoxied into the frame in a five-by-five array with no spacing between each cube. The FRAGMAT was mounted onto one of the 203 mm square faces of the explosive box as shown in Figure 5. Five dry field (tetryl) charges 29 mm long x 29 mm diameter were placed in the opposite end of the explosive box to initiate the Composition B. From previous tests, this configuration was expected to produce fragment cubes with the specified average velocity of 2530 ± 90 m/s.

The setup was aligned so that the FRAGMAT in the fragment projector was aimed through the window in the blast shield to the centre of the Cartridge Case. Five 600 mm lengths of detonating cord (Redcord) were taped at one end into the dry field charges: the free ends of the detonating cord were in turn taped into a cardboard tube containing approximately 20 g of high explosive PE-4. A single electric detonator was used to initiate the PE-4. Video cameras and a 16 mm high speed camera operating at approximately 16000 frames per second were used to monitor and record the tests. The high speed camera was switched on and the detonator initiated when the camera reached its nominal framing rate.

Four high frequency pressure transducers were used to measure any blast overpressure during the tests. These transducers were mounted at ground level, two at 12 m and two at 18 m behind the test item, at 45° to the line of fire of the fragment projector.

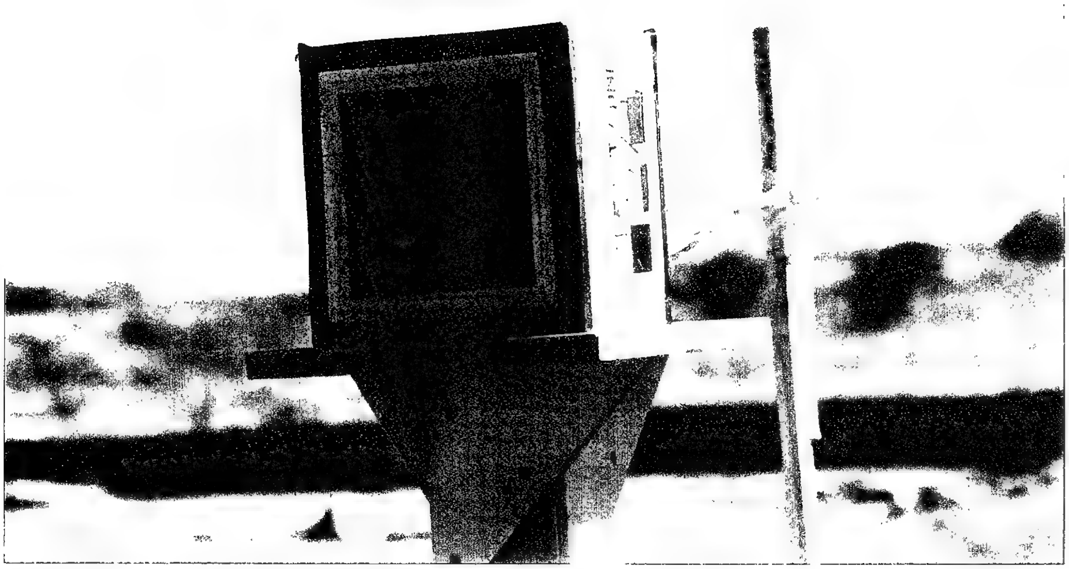

Figure 5: FRAGMAT in a fragment projector

4.2 Results

The results for both BS NACO tests were very similar. The video and high speed film records indicated that, on impact, each Cartridge Case ruptured: pieces of Case and unburned propellant were thrown up to 70 m from the site. Figure 6 shows the test site after the first test including the horizontal witness plate which was slightly bowed. The Case debris recovered from the first test is shown in Figure 7.

With the LOVA propellant, the second test was very similar to the BS NACO results, however the response in the first test was significantly more violent. The horizontal witness plate was folded over completely as shown in Figure 8 and 'inside' the plate there was substantial gouging or scoring with some brass embedded in the plate, evidence of a partial detonation occurring in the LOVA propellant. Only a few small pieces of the Case were recovered (see Figure 9) up to 100 m from the site.

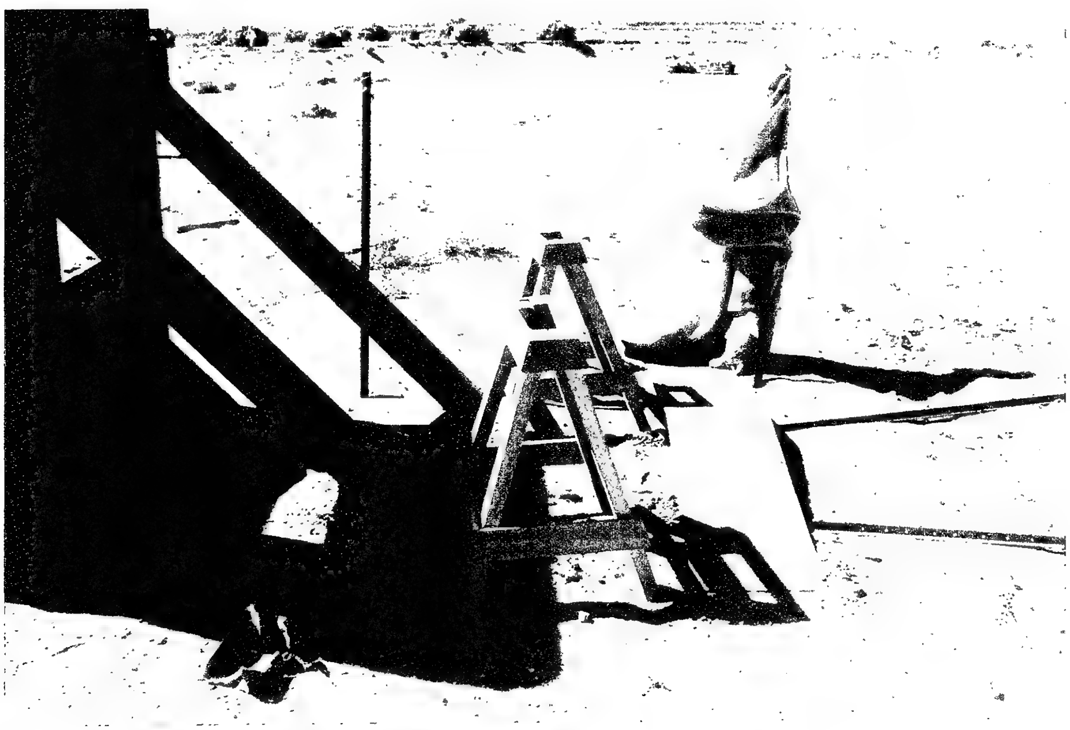

Figure 6: Test site after BS NACO Fragment Impact Test 1, including bowed witness plate

Figure 7: *Recovered Case debris from BS NACO Fragment Impact Test 1*

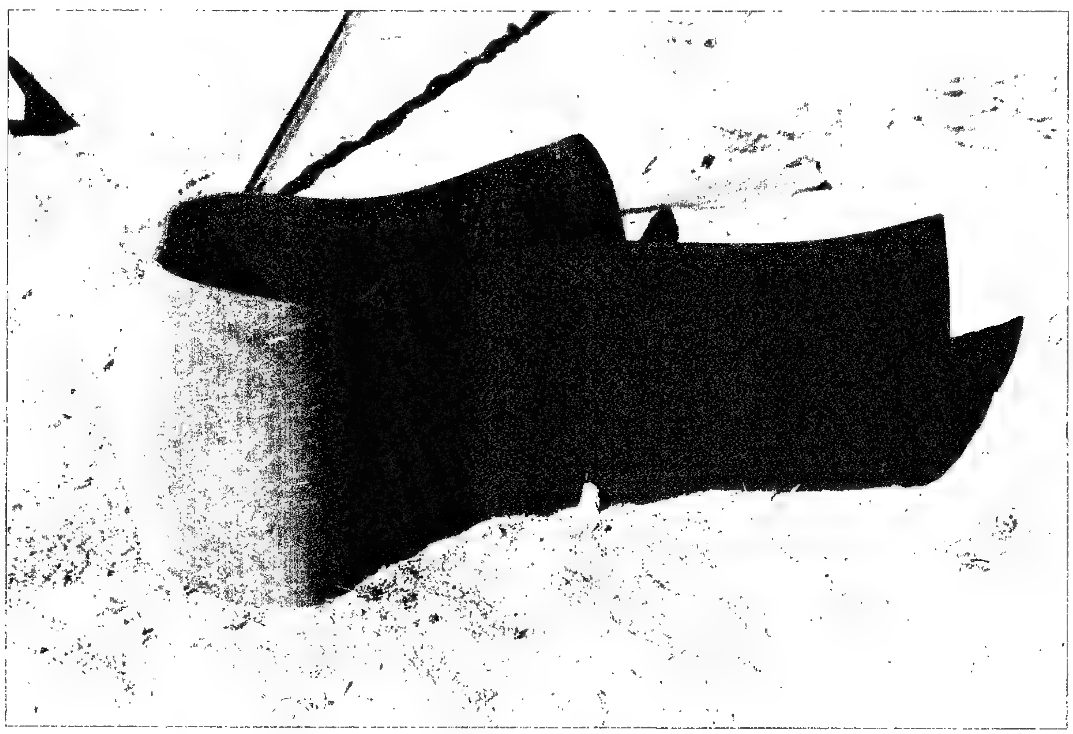

Figure 8: *Witness plate after LOVA Fragment Impact Test 1*

Figure 9: Recovered Case debris from LOVA Fragment Impact Test 1

A summary of the recovered test debris, and estimates from the debris of the number of cubes to strike both the Cartridge Cases and the vertical witness plates are given in Table 2. From the high speed film records the average velocity of the first fragment to impact the test item is also included. More cubes impacted each Case in subsequent frames: each frame reduces the average velocity of those fragments by approximately 100 m/s. The accuracy of the average velocity as calculated is estimated at +60 / -170 m/s. The greater error towards a slower velocity can occur if the frame count on the camera is too low: this is possible if the actual moments at which the cubes leave the surface of the fragment projector, and when the first cube strikes the test item, occur between camera frames.

Table 2: Post Test Summary - Fragment Impact Tests

	BS NACO Propellant		LOVA Propellant	
	Test 1	Test 2	Test 1	Test 2
Mass of recovered propellant (kg)	<0.3	<0.2	nil	<0.3
Mass of recovered Cartridge Case (kg)	6.2	5.45	0.65	4.05
Number of cubes to strike the Cartridge Case	≥3	≥6	≥1	≥3
Number of cubes to strike the vertical witness plate	≥10	≥9	≥8	≥12
Distance from Fragment Projector to Cartridge Case (m)	3.9	5.2	3.9	5.2
Fragment Velocity (m/s)	2880	2980	2760	2820

All blast overpressure gauges showed a significant overpressure from the fragment projector. Figure 10 shows a blast overpressure versus time plot from one of the four tests: this plot, with its second peak approximately 14 msec after the first, was typical of the results obtained with inert test items during instrumentation verification tests. Table 3 shows the measured peak overpressures from each test. Results from the first LOVA test are slightly higher than for the other three tests, which may be due to the detonation of some of the propellant grains. However the levels recorded are below the upper limit of values recorded from the fragment projector with an inert test item and hence a significant contribution from the LOVA propellant cannot be identified.

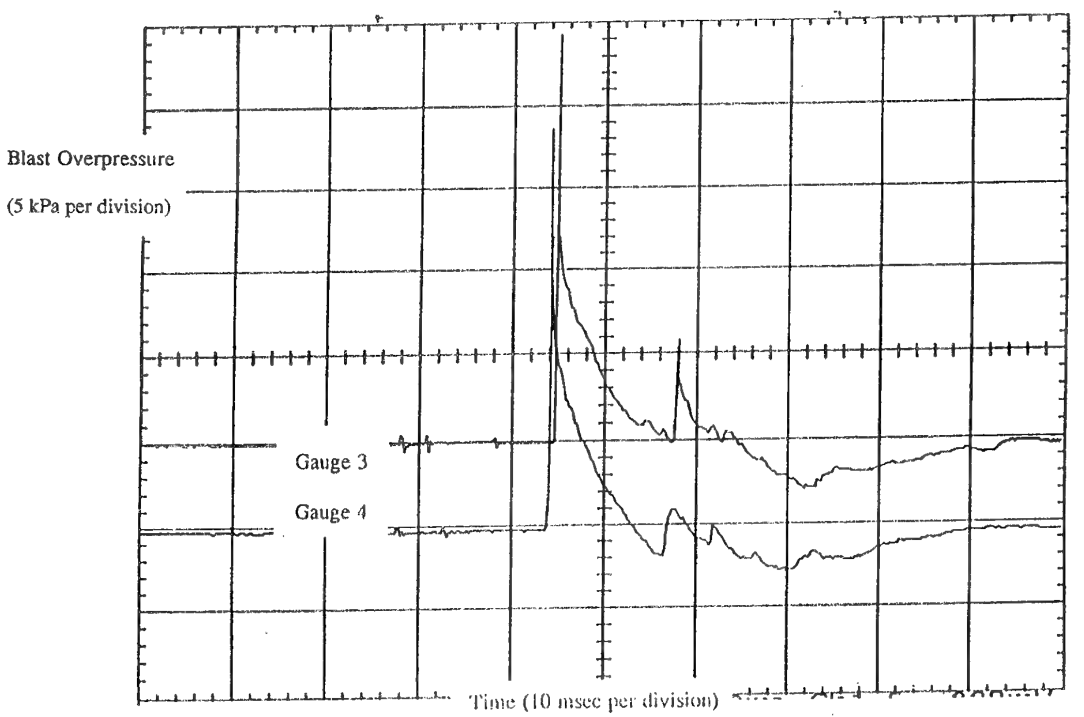

Figure 10: 'Typical' blast overpressure versus time plot from Fragment Impact Tests (from BS NACO test 1 - gauge numbers 3 and 4)

Table 3: Peak Overpressures - Fragment Impact Tests

Gauge Number	Distance from Cartridge Case (m)	BS NACO Propellant		LOVA Propellant	
		Test 1 (kPa)	Test 2 (kPa)	Test 1 (kPa)	Test 2 (kPa)
1	12 - right	45.5	48.2	59.3	51.0
2	12 - left	42.0	44.8	56.5	46.9
3	18 - right	24.1	24.8	31.0	28.2
4	18 - left	23.4	27.6	25.5	25.5

5. Fast Cookoff Tests

5.1 Test Description

The fast cookoff tests were conducted in May 1993 in accordance with NATO STANAG 4240[4]:

'The test consists of engulfing the ordnance in a fuel fire and recording its reaction as a function of time. The ordnance is suspended above the burning fuel and the test is terminated upon completion of the reaction(s) of the ordnance.'

Only one test was conducted with each propellant type, as the test results were not meaningful as described below.

For each test, a 9 m x 9 m x 0.4 m deep pit was prepared and lined with a plasticised waterproof lining, and a steel 'A'-frame was placed diagonally in the centre of the pit to support the Cartridge Case. Water was added to the pit, to within approximately 150 mm from the top of the pit walls.

Twenty-four 200 litre drums of BP AVTUR Aviation Fuel were poured into the pit. The Cartridge Case was suspended 600 mm above the surface of the fuel as shown in Figure 11. Four thermocouples were clamped to steel supports 200 mm from the surface of each Cartridge Case at locations fore, aft, starboard and port, along a horizontal plane through the centreline of the Case, to measure flame temperature throughout the tests. Then the fuel was ignited.

The tests were recorded using video cameras.

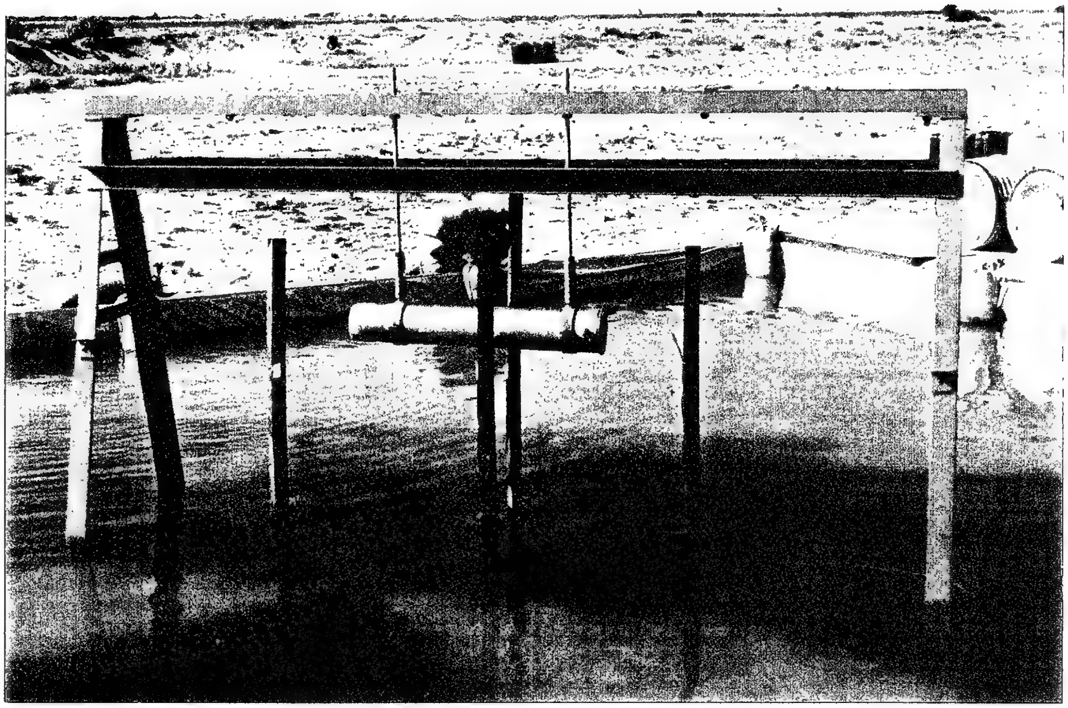

Figure 11: Fast Cookoff Test setup

5.2 Results

In both tests, the fire burned for approximately 10 minutes. At some time during each fire the brass Cartridge Cases melted and propellant fell into the water beneath the burning fuel. This result was predicted and hence only one test of each propellant type was conducted. Figure 12 shows the pit after the LOVA propellant fuel fire test: the result for BS NACO propellant was the same.

After the BS NACO and LOVA tests, approximately 4 kg and 3 kg of resolidified brass was recovered from the base of the 'A'-frame, together with 6.5 kg and 8 kg of unburned propellant, respectively.

There were no blast overpressures measured during either test.

Temperature versus time records for the two tests are shown in Figures 13 and 14.

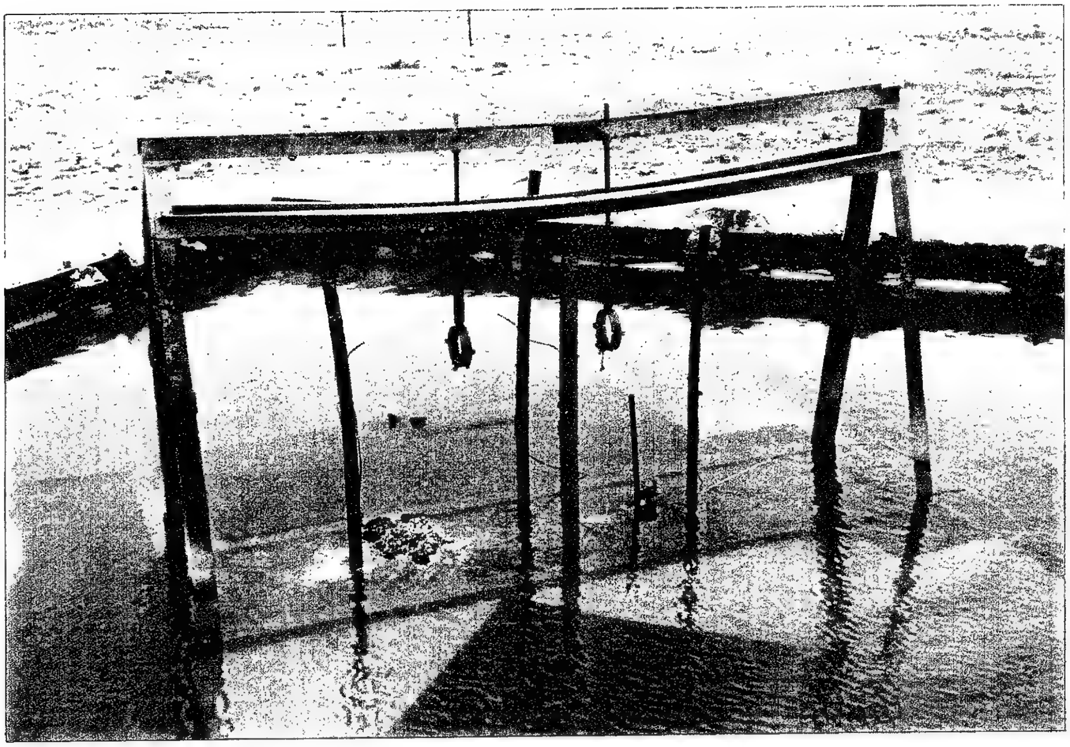

Figure 12: Test site after LOVA Fast Cookoff Test

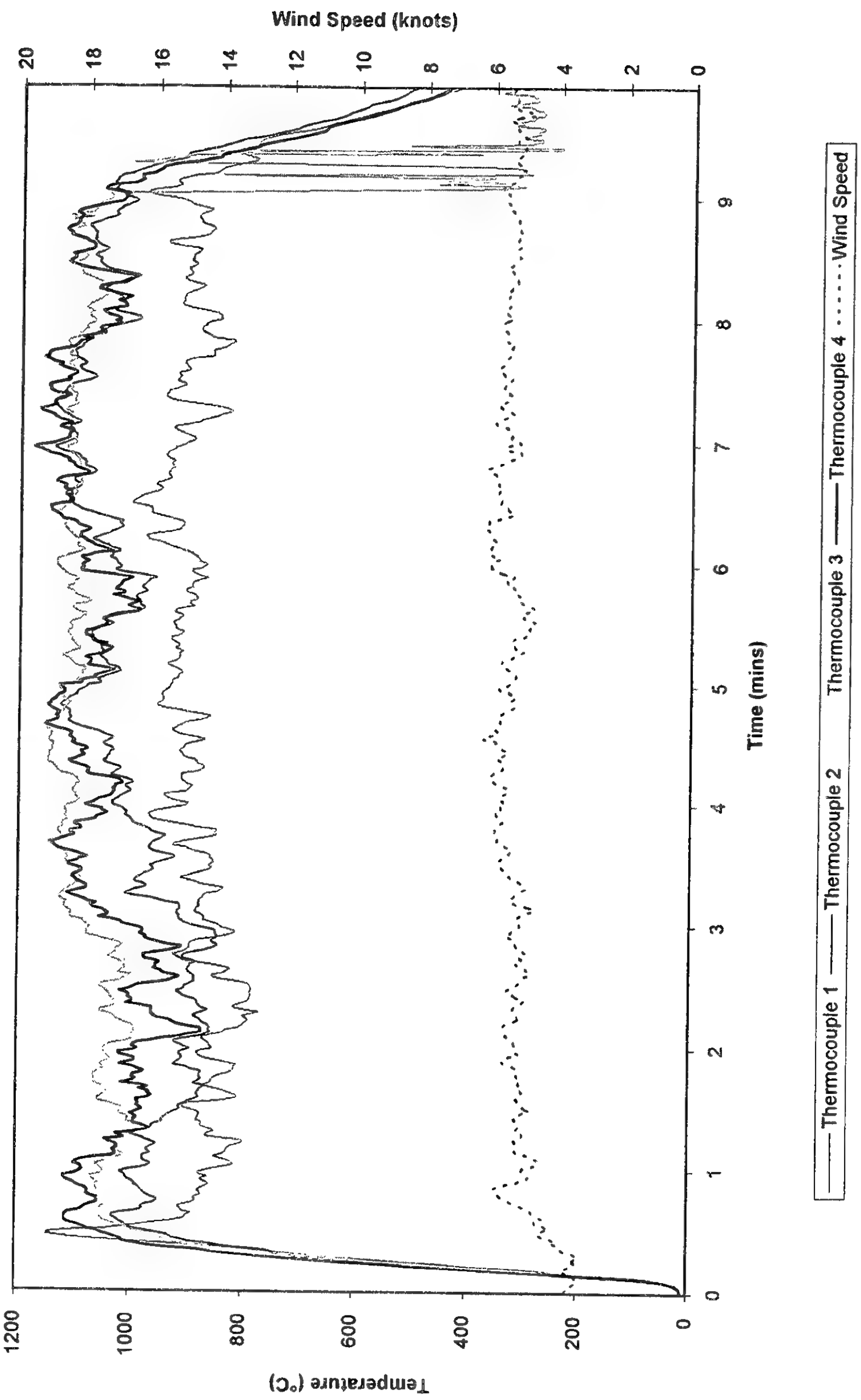

Figure 13: Temperature versus time - BS NACO Fast Cookoff Test

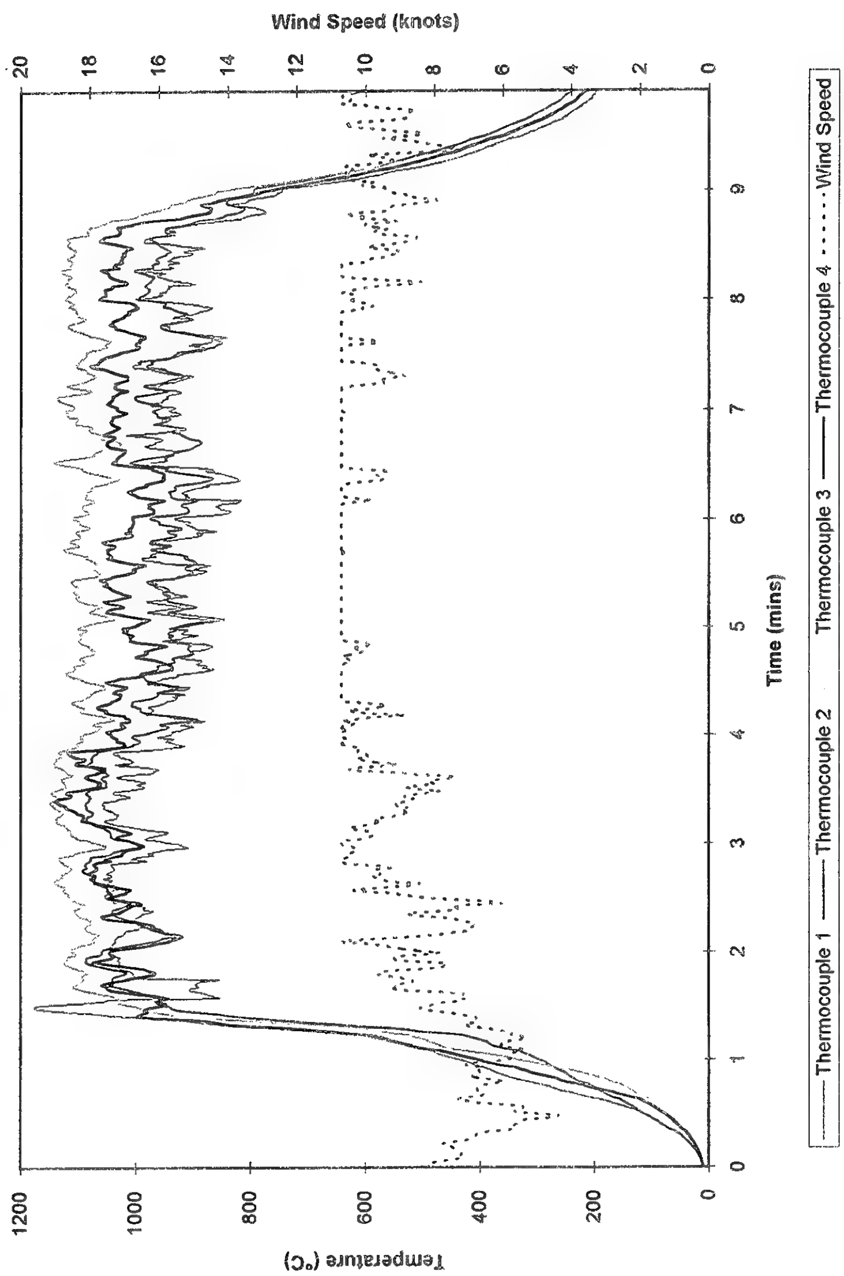

Figure 14: *Temperature versus time - LOVA Fast Cookoff Test*

The times taken after fuel ignition for the flame temperature to reach 550°C, and the average flame temperatures from this time until the fires started to burn out are given in Table 4.

Wind speed versus time, as measured by an anemometer on the roof of the blockhouse at the site, is also plotted on Figures 13 and 14.

Table 4: Temperature Data - Fast Cookoff Tests

Gauge Number	Location relative to Cartridge Case	BS NACO Propellant		LOVA Propellant	
		Time to 550°C (s)	Average Temp (°C)	Time to 550°C (s)	Average Temp (°C)
1	Fore	16	891	71	948
2	Starboard	17	1002	78	962
3	Aft	17	1060	76	1080
4	Port	15	1056	71	1017

6. Slow Cookoff Tests

6.1 Test Description

The slow cookoff tests were conducted in May, August and September 1992, in accordance with US MIL-STD-2105A(NAVY)[2], Section 5.1.6:

'The test consists of subjecting the test item to a gradually increasing temperature at a rate of 6°F (3.3°C) per hour until reaction occurs. The test item may be preconditioned at the munitions upper environmental temperature limit for eight hours prior to the start of the test. Temperatures and elapsed time shall be observed and measured continuously. A minimum of two items shall be tested.'

Two tests were conducted with each propellant type.

For each test, an oven was constructed comprising three base modules, each with two heating elements and one fan. The four oven walls and lid were fabricated from fibreglass board around the base modules. Resistive Temperature Devices (RTDs)

were mounted in the oven lid to monitor and control the oven air temperature. These RTDs were connected directly to a controller bank consisting of independent Eurotherm 815P PID programmable control units, each accepting a single RTD input. Each control unit supplied an output signal to a single thyristor in a thyristor bank. Power cables ran from the thyristor bank to the heating elements and fans in the base modules of the oven.

The Cartridge Cases were placed into the ovens and thermocouples were secured to the Cases at different locations to monitor their external temperature. Figure 15 shows a slow cookoff oven ready for test. When each test commenced, the oven heaters and fans and the temperature controllers were switched on: the oven air temperature was stepped to 60°C and maintained at this level for eight hours, then increased at the rate of 3.3°C per hour until a reaction occurred.

The tests were recorded using video cameras.

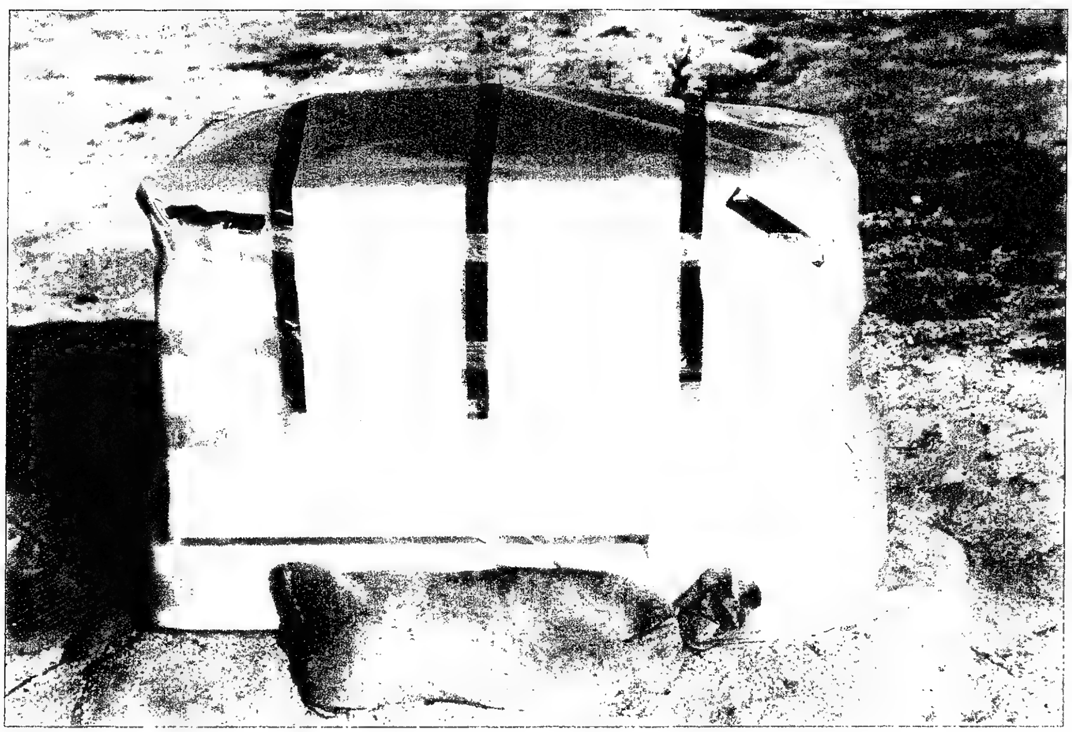

Figure 15: Slow Cookoff Test setup

6.2 Results

The results in both LOVA tests were very similar. At an oven air temperature of approximately 150°C, the propellant ignited and commenced burning. No debris was thrown from the site and after the tests the Cases were still in position inside the ovens, as shown in Figure 16. No blast overpressures were recorded during either test.

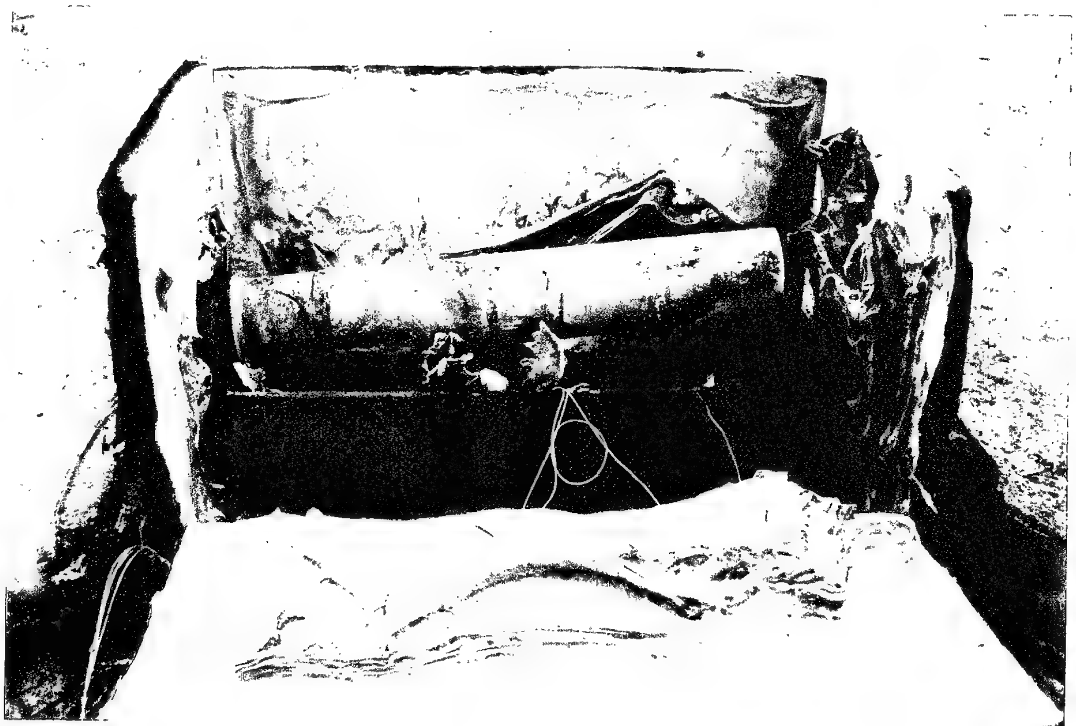

Figure 16: Cartridge Case after LOVA Slow Cookoff Test 1 - oven partially disassembled

With the BS NACO propellant, reactions occurred in both tests at approximately 135°C. The first test result was similar to those of the LOVA propellant: the propellant ignited and burned and after the test the Case was still in position in the oven. In the second test however, the Case deflagrated. Burning propellant was showered up to 35 m from the oven and pieces of Case debris were found up to 55 m from the site. Figure 17 shows the base of the Case which was located 26 m from the oven. A maximum of 4 kPa blast overpressure was recorded at 10 m from the oven when the Case deflagrated.

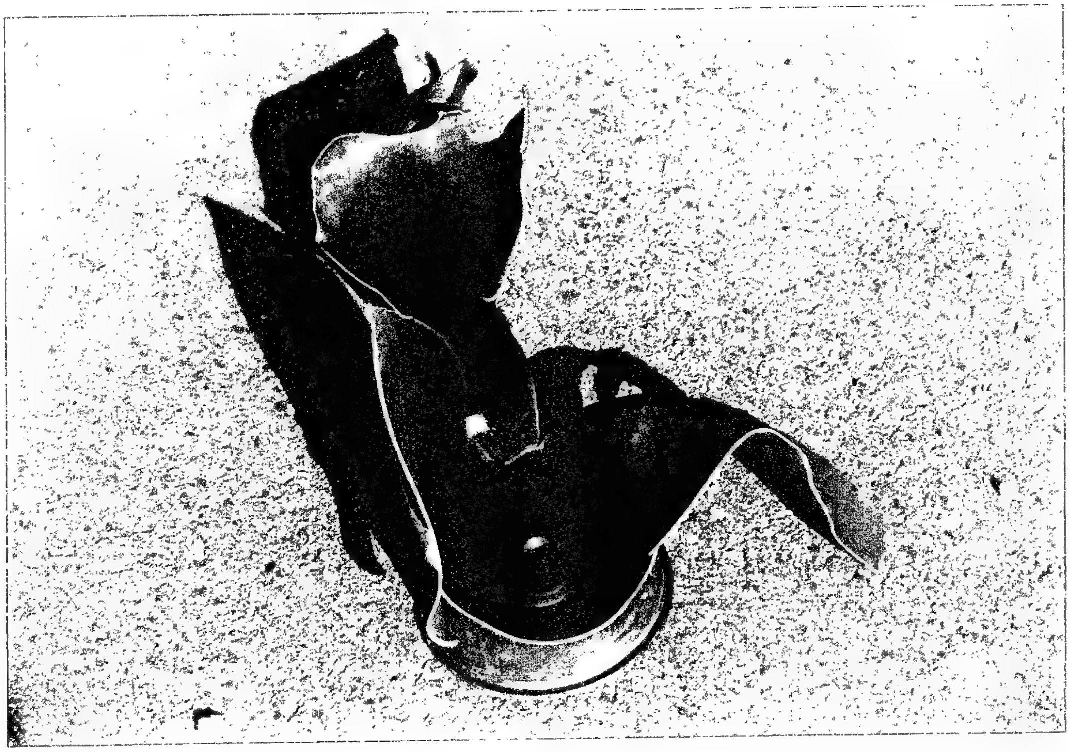

Figure 17: Base of Cartridge Case after BS NACO Slow Cookoff Test 2

An examination of the temperature versus time data from the two BS NACO tests shows a gradual rise in Case temperature during the last hour of the test, indicating that an exothermic reaction was occurring in the propellant. Figure 18 shows temperature versus time data for the Case thermocouples in the second BS NACO test, for the five hour period before the reaction. The exothermic reaction was much less significant with the LOVA propellant, as shown in Figure 19.

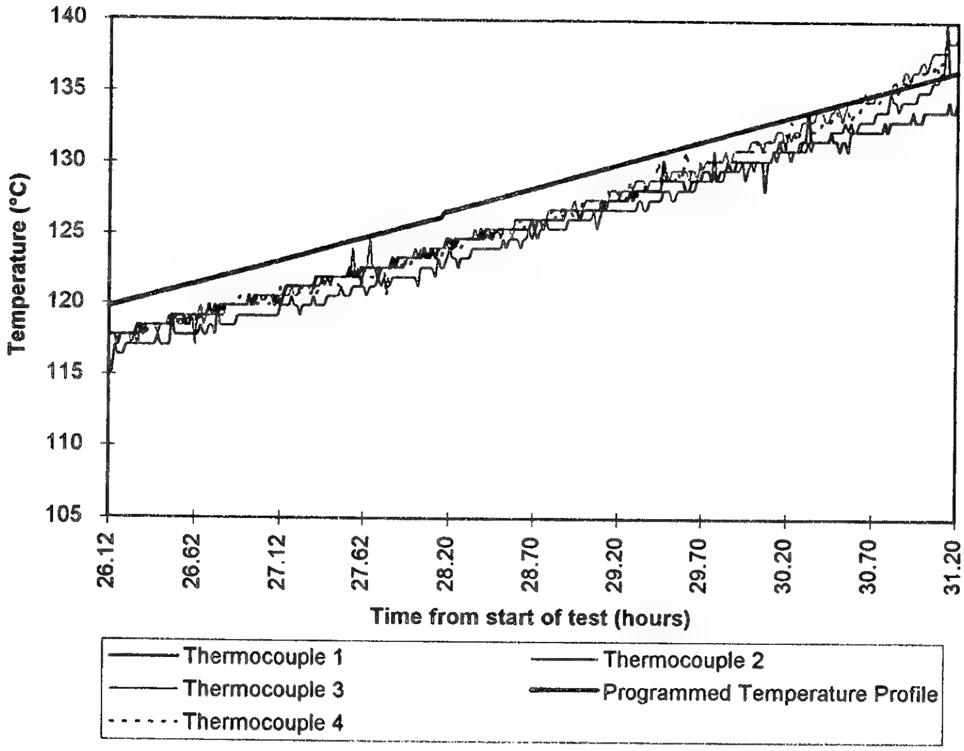

Figure 18: Temperature versus time - BS NACO Slow Cookoff Test 2

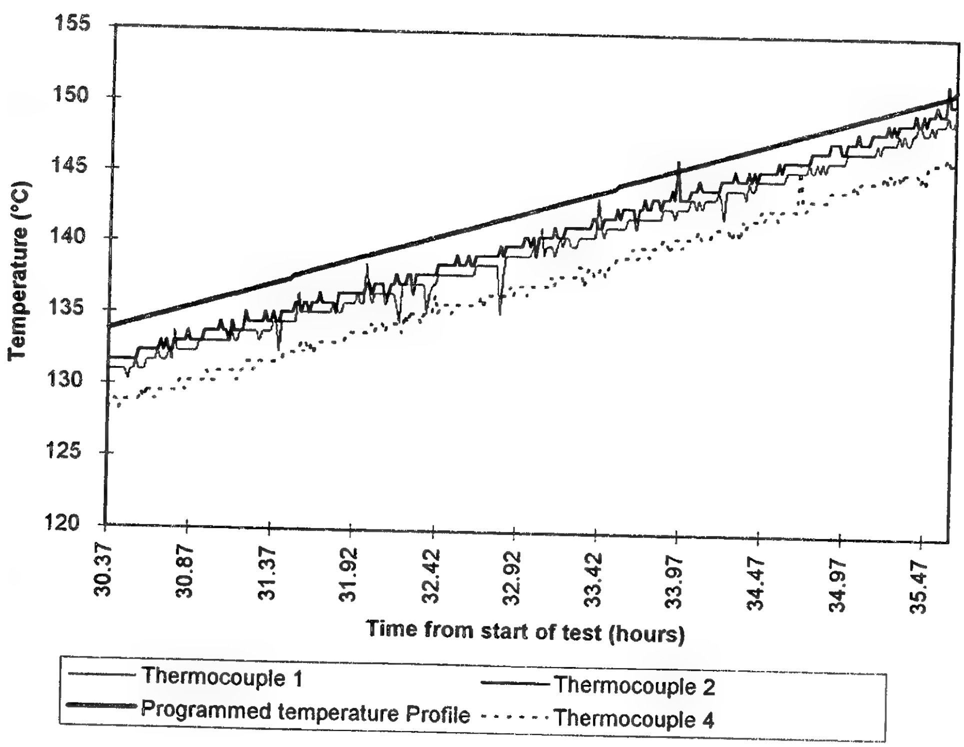

Figure 19: Temperature versus time - LOVA Slow Cookoff Test 2

7. Discussion

The results of these tests, using the response definitions contained in DI(G) LOG 07-10[1], are summarised in Table 5 below. This table also includes the pass/ fail criterion for each test.

Table 5: Test Results and Pass/Fail Criteria

Test	Pass/Fail Criterion	BS NACO Propellant	LOVA Propellant
Bullet Impact	Burning	2 Burning	2 No reaction*
Fragment Impact	Burning	2 Explosion	1 Partial Detonation 1 Explosion
Fast Cookoff	Burning	No reaction*	No reaction*
Slow Cookoff	Burning	1 Burning 1 Deflagration	2 Burning

* See text below

The results in both fast cookoff tests were not unexpected given the relatively low melting point of the brass Cartridge Cases, and only one of each test was scheduled on the assumption that this result would occur. When the Cases melted, the propellant fell into the water beneath the fuel and any burning was extinguished. Hence, both results were classed as 'No reaction'. It is suggested that in a 'real' fire scenario (where no water is present) the propellant would have continued to burn when the Cases melted, leading to 'Burning' reactions with both propellant types.

From STANAG 4240[4], there are two flame temperature requirements to constitute a valid fast cookoff test. The first is an average flame temperature of 870°C on all thermocouples, and the second is that the time to reach 550°C shall be less than 30 seconds. In a previous report[5] which describes the effect of wind on flame temperature during fast cookoff tests in Australia, it was recommended that in order to maximise the likelihood of a valid test, two conditions should be satisfied:

i. Fast cookoff tests should not be conducted in conditions where the wind speed exceeds 3 knots, and

ii. The test item should be suspended such that its horizontal centreline is 600 mm above the initial fuel surface (higher only for bulky test items).

At the time of writing reference 5, it was considered that the limitation on wind speed was the more critical of these two parameters. Results from the fast cookoff tests reported here suggest that the height above the initial fuel surface may be equally important, if not more so. In both tests, the wind speed was greater than 3 knots as shown in Figures 13 and 14, yet the average flame temperature requirement was satisfied as indicated in Table 4. The time to reach 550°C in the LOVA test, where initial wind speed was approximately 6 to 7 knots, was significantly greater than 30 seconds. The video records of this test confirm that the initial flame front was very slow to spread across the fuel surface because of the wind, although this is not believed to have influenced this test result in any way. For future tests, in order to satisfy both temperature requirements for a valid test it is recommended that the test item be suspended 600 mm above the initial fuel surface and that the upper wind limit for tests be raised to 5 knots.

The slow cookoff results with the BS NACO propellant illustrate a problem which exists with each of the full scale IM tests. These tests are pass/fail or go/no-go tests, and do not provide any indication of how far a result may be from the acceptable or unacceptable limits. Each of the Cartridge Cases used in these tests was filled with propellant by P&EE, Port Wakefield, and the Cork Plugs were crimped into the mouths of the Cases using the same crimping tool, yet in one of the BS NACO tests, the pressure buildup when the propellant ignited was sufficiently slow to allow the Cork Plug to eject and relieve the confinement provided by the Case. In the second test however the pressure rise was more rapid and the Cork Plug did not release in time to prevent a more violent response from the Cartridge Case.

The heating rate specified for the slow cookoff test (6°F/hr = 3.3°C/hr) has been the subject of considerable discussion in the international IM community since this test was adopted, with a general consensus that is does not represent any real-life threat scenario. US authorities are, however, reluctant to abandon this heating rate for which such a large data base of results already exists. A small number of studies[6] have looked at the life cycle of some ordnance items and identified likely slow cookoff scenarios, in an attempt to determine a more realistic slow cookoff heating rate. It is believed that more meaningful information would be obtained if slow cookoff tests were conducted at a heating rate (or rates) identified as the most likely from the munition threat analysis.

With the LOVA bullet impact tests, the high speed film records confirmed that the propellant did ignite on impact, however there was no sustained burning as the propellant was immediately extinguished when the Cases ruptured. Hence these results were classed as 'No reaction'.

While the bullet and fragment impact tests both examine the response of a munition to projectile impact, the different test geometries and impact energies can lead to very different reactions as observed in this test series. Results from all four fragment impact tests were significantly more violent than those from the bullet impact tests. While the fragment impact velocities were all above the limit specified in MIL-STD-2105A(NAVY)[2], they were similar and hence allow a comparison of the two propellant types.

The two LOVA fragment impact results provide another example of the problem described above where the results from full scale tests do not give any indication of the 'safety margin' of a good result. While a partial detonation with the LOVA propellant is possible given the presence of RDX in the propellant, it is not possible to determine whether this or a milder explosion is the more statistically likely result. The generally accepted theory of why identical test items have occasionally yielded grossly different results in fragment impact tests is that in these more violent tests, the fragment cubes may strike the target 'edge-on' or 'corner-on', or in pairs or clusters. Not only does this latter problem have the potential to increase the effective impact energy, but if the first cube strikes and penetrates the test item and damages the energetic material in the vicinity of its path, then subsequent cubes impacting very close to the first may strike 'damaged' energetic material. It is known that 'damaged' energetic material may be substantially more sensitive to impact[7]. For this reason, the time and spatial distribution of the cubes at impact is a critical parameter in determining a munitions' response to the multiple fragment impact test. This is a parameter which is extremely difficult to measure or control with the current fragment impact test procedure. During FY94/95, EOD are conducting a task to investigate improved techniques for the multiple fragment impact test which will lead to better control of the aim and spread of the cubes at the target, as well as more accurate techniques for measuring fragment velocity.

With regard to the RAN 5"/54 Cartridge Case, the IM tests reported here demonstrate that the current BS NACO propellant exhibits a mixed response to both the thermal and impact stimuli, with acceptable results in fast cookoff and bullet impact tests, but not in slow cookoff or fragment impact. Alternatively, the LOVA propellant reacts favourably to both thermal stimuli, but has demonstrated the potential to detonate when subjected to a sufficiently severe impact stimulus. It should be noted however that these conclusions are based on only two of each type of test (only one for Fast Cookoff) because of the costs involved, and so the results should be considered as indicative, rather than definitive.

It is believed that a threat analysis of the 5"/54 Cartridge Case would indicate that a thermal hazard was more likely than an impact threat, considering in particular the location of shipboard storage magazines, and hence from IM considerations, greater emphasis should be placed on the thermal response of any alternate propellants for the RAN 5"/54 Cartridge Case.

8. Acknowledgements

The conduct of fourteen full scale insensitive munitions tests required a significant effort from Messrs Schebella, Fraser, Evans, Footner, Braithwaite, Bull and Obst from EOD-Salisbury, as well as generous cooperation from staff at P&EE, Port Wakefield. Their contributions are gratefully acknowledged.

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Full Scale Insensitive Munitions Testing of the
RAN 5"/54 Cartridge Case

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ABSTRACT

During the period May 1992 to March 1994, a series of 14 full scale Insensitive Munitions tests were conducted on RAN 5"/54 Cartridge Cases containing the standard BS NACO propellant and a Low Vulnerability Ammunition (LOVA) propellant formulation 'XM 39'. Tests were multiple bullet and fragment impact, and fast and slow cookoff. The results of these tests are presented and some implications are discussed.